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Design of Compact Heat Exchangers for Aero-Gas Turbines

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The Company

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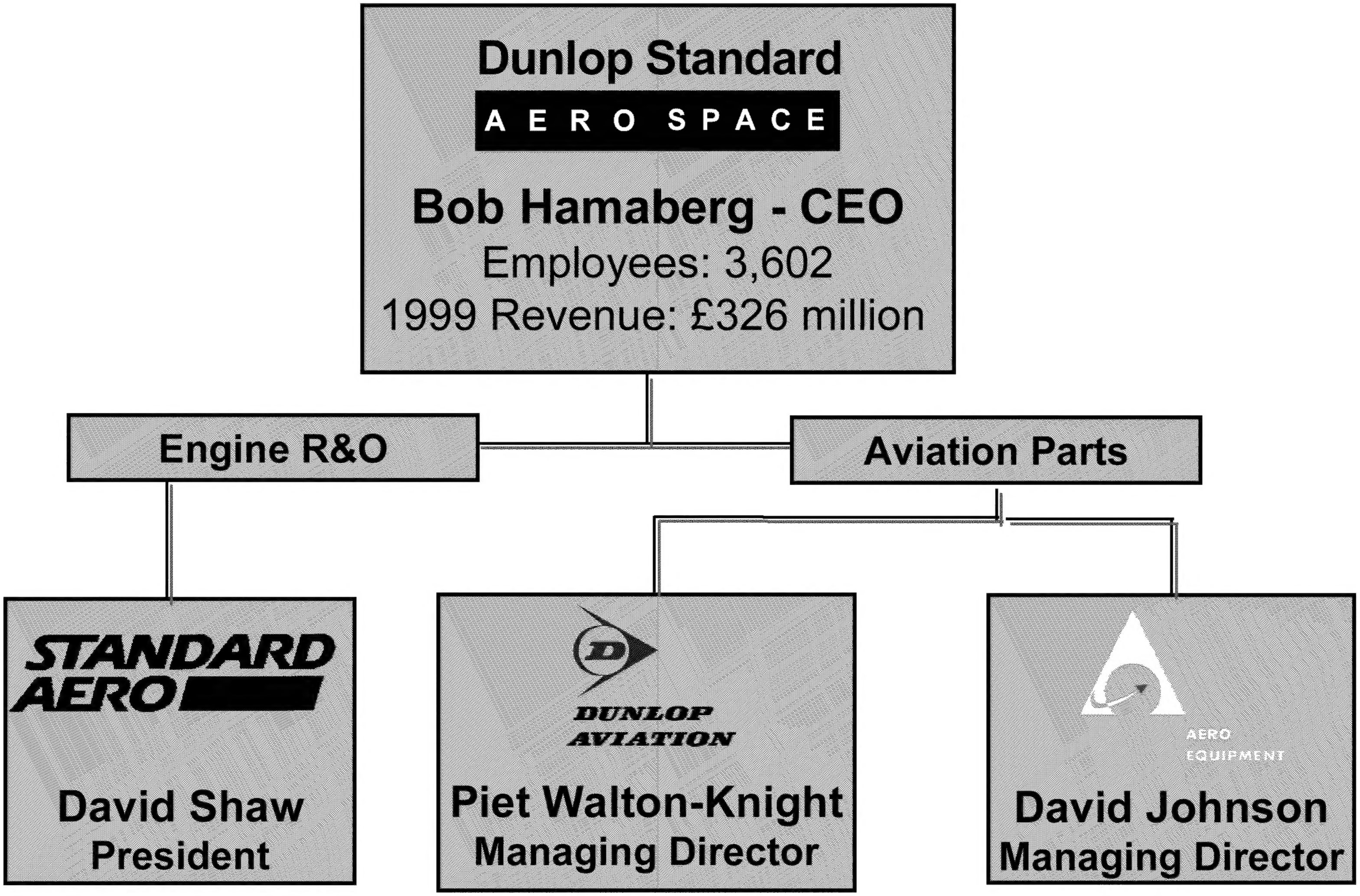

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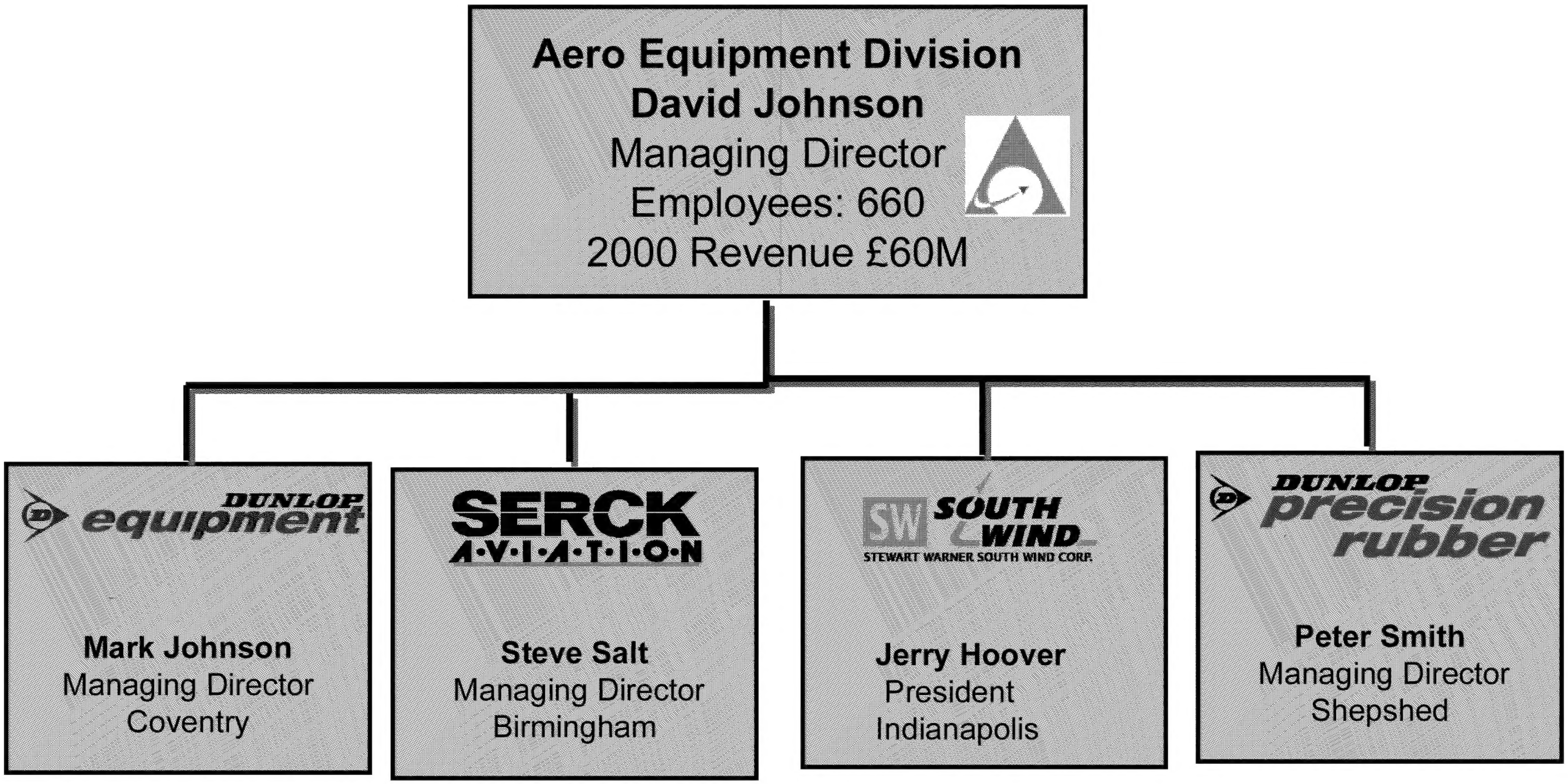
Aero Equipment Division
David Johnson
Managing Director
Employees: 660
2000 Revenue £60M
DUNLOP equipment
Mark Johnson
Managing Director
Coventry
SERCK AVIATION
Steve Salt
Managing Director
Birmingham
SW SOUTH WIND
STEWART WARNER SOUTH WIND CORP.
Jerry Hoover
President
Indianapolis
DUNLOP precision rubber
Peter Smith
Managing Director
Shepshed

The Company

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Headline Figures

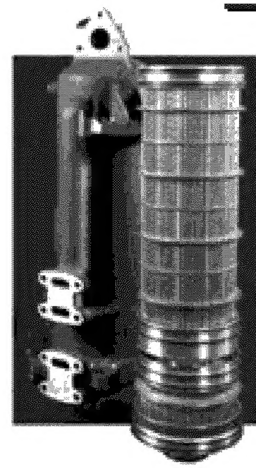
- 2000 Sales £15m
- Employees 130
- Sole Market in Aerospace (91% export)
  - 85% Civil
  - 15% Military
- OEM - 59% of sales
- Spares - 27% of sales
- R&O - 14% of sales

Product Applications include

- Pratt and Whitney
  JT8, JT9, PW2000, PW4000, PW6000, F100
- Rolls Royce
  Tay, Adour, RB211 524 & 535, Pegasus, Trent, RTM322
- General Electric
  F404, CF34
- SNECMA
  CFM56 All Marks
- Boeing 777
- BAe Harrier, Hawk

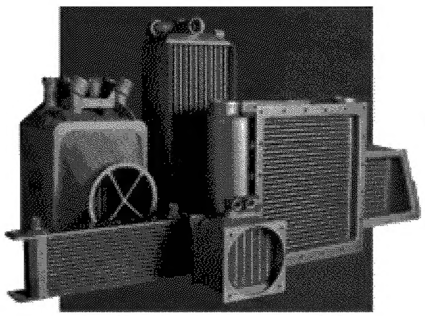
The Products

Shell & Tube



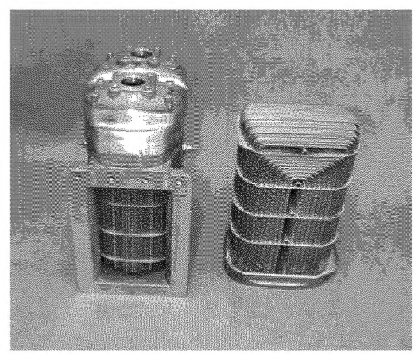
- Compact aluminium tubular construction offers the advantage of low weight
- Modular design for repair and overhaul provides low cost of ownership
- Well proven design and robust construction meets High Mean Time Between Failure requirements

Plate & Fin



- Compact aluminium construction offers the advantage of low weight and cost.
- Brazing technology used provides high joint integrity

High Temperature



- Operating at approximately 1200°F to provide positive cooling to bearing chambers.
- Compact inconel tubular construction offers exceptionally long service life

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Existing Products

Type	Applications			Heat transfer area/volume
	Fuel/Oil	Air/Oil	Air/Air	(Compactness)
• Tubular	✓	✓	✓	650 m^2/m^3
• Plate - Fin	✓*	✓	✓	800 - 1500 m^2/m^3

* Low Pressure & Temperature applications

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Metal Foam Heat Exchanger

Construction

- Use of Metal foam, (nickel or aluminium) to increase heat transfer.
- Several designs under consideration.
- Rapid development of product expected.

Benefits

$\Rightarrow$ Cost Reduction

$\Rightarrow$ Weight Reduction

$\Rightarrow$ Performance Improvement

Metal Foam

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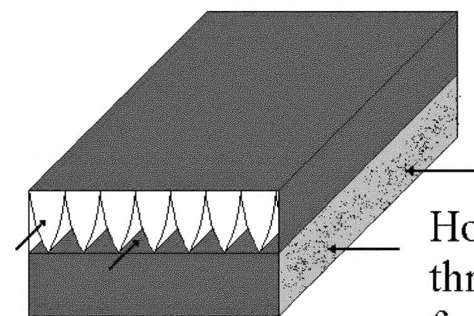
Design Option - 1

- ⇨ The heat exchanger built up of alternate plates.
- ⇨ Note: the foam can be brazed to the plates.

Plate Fin/Foam Heat Exchanger



Hot fluid flows through the metal foam

Cooler fluid flows around the fins

Fig.1

Metal Foam

Design Option - 2

⇨Contact between tubes and foam is fixed by brazing.

⇨Extended secondary surface for heat transfer.

⇨Increased turbulence of the shell-side fluid.

⇨The materials of construction have the same thermal expansion.

Tube - Foam Heat Exchanger

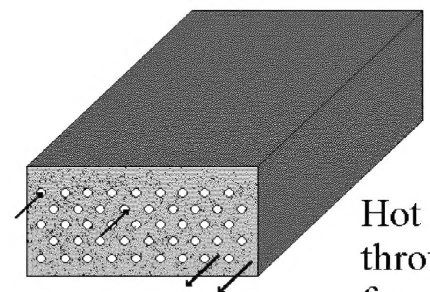


Fig.2

Metal Foam

Design Option - 3

Rotating Air/Oil Heat Exchanger
& Separator:

Fig.3

⇨The Retimet® uses centrifugal action to force the denser oil to separate from the less dense air.

⇨Rotational energy required is available within the gearing system.

⇨Heat exchange possibilities present in such a configuration.

Metal Foam

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Key points for consideration

Using metal foam:

- ⇨ Is the pressure drop acceptable ?
- ⇨ Fouling is likely to occur with a small-celled metal foam. Therefore, can we make larger cells without losing performance, or should it have a filter added?
- ⇨ Will Foam break/fragment under operation?

Metal Foam

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Compactness of the Metal Foam HE

Estimated @ $\approx$2500 m^2/m^3

Compare with current tubular of 650 m^2/m^3

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Design considerations

- Heat Transfer Performance & pressure loss
- Economic manufacturing cost
- Size, installation and removal for overhaul
- Dynamic loading induced from engine including vibration, blade out, manoeuvre
- Static loading from internal fluid pressures
- Thermal structural loading
- Material properties
- Fluid Properties
- Contamination / Fouling
- Repair and overhaul
- Life

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Structural loading

⇨Design is evaluated by Finite Element Analysis (FEA) to determine resonant frequencies and displacement of the assembly and component parts over the engine frequency range (typically from 5 to 3000 Hz with 20G load applied above 100Hz).

⇨Static FEA for pressure loads

⇨Dynamic FEA for blade out (120G) and manoeuvre loads

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⇨Thermal loading: particularly in the case of high temperature heat exchangers, a transient thermal FEA is completed using a validated model. This evaluates the induced metal temperatures and strain range throughout an entire flight cycle. A fatigue life analysis can be completed using the strain range, material properties and the number of defined engine cycles

⇨Computation Fluid Dynamics (CFD) is used to identify flow patterns (hot spots, reduced flow zones) within the unit which enables us to refine our heat transfer models. It also provides a good indicator of whether flow induced vibration will be a problem, and if so, how effective different design solutions will be.

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Testing

Component Certification for flight worthiness testing will include:

- Vibration
- Pressure - including Proof/Burst/cycling
- May include PTF - pressure/temperature/flow cycling (although this may be avoided with the use of validated FEA)
- Impact
- Fire
- Icing
- Bird Strike/FOD.

Pass by analysis for sand, dust & fungus.